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ABSTRACT

The transformation of episodic inputs to semantic representations was studied in two very similar tasks. In one, subjects were required to infer the underlying four-term linear ordering from three comparative sentences such as, "The teacher is taller than the doctor." In the second task, subjects inferred underlying 4- and 5-digit strings, e.g., 5719, from series of three or four digit pairs, such as 57, 71, 19 or 19, 57, 71. In both tasks, variations in input order produced large, significant differences in the proportion of orders or strings correctly constructed. The following principle explains a major feature of these data as well as many of the errors subjects made: "As the twig is bent, so the tree's inclined." (Author)

CONSTRUCTIVE PROCESSES IN MEMORY FOR ORDER[1]

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Abstract

The transformation of episodic inputs to semantic representations was studied in two very similar tasks. In one, Ss were required to infer the underlying four-term linear ordering from three comparative sentences such as, "The teacher is taller than the doctor." In the second task, Ss inferred underlying 4- and 5-digit strings, e.g., 5719, from series of three or four digit pairs, such as 57, 71, 19 or 19, 57, 71. In both tasks, variations in input order produced large, significant differences in the proportion of orders or strings correctly constructed. The following principle explains a major feature of these data as well as many of the errors Ss made: "As the twig is bent, so the tree's inclined."

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CONSTRUCTIVE PROCESSES IN MEMORY FOR ORDER

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A number of recent studies have shown that when a S tries to learn or remember a set of sentences that describe a linear ordering, what is actually remembered is the linear ordering, not the individual sentences. The recent studies of both Barclay (1973) and Potts (1972) are quite convincing on this score. Assuming that Ss do construct a semantic representation of linear ordering from the episodic sentence inputs, we wondered how the constructive process works. Barclay has shown that to some extent the constructive process can be controlled by instructions to the Ss. But in cases where it is clear that the S is engaging in constructive activities and where it is clear what the construction is, there remains the question of how the process operates and what variables influence its operation. In the present paper, we were concerned with the effects of the order of episodic inputs.

In a four-term series problem such as Potts investigated there are six different ways in which the three input sentences can be ordered. The first experiment was concerned with the effects of these orders on constructive memory. What we asked our Ss to do was to listen on each trial to a set of three sentences and then, when signaled that the series was complete, to write down the four terms in order. The sentences were all comparative sentences using either "taller" or "shorter," and the elements were the four names of

professions: doctor, teacher, farmer and soldier (two-syllable, high frequency nouns). So, for example, the S might hear "The teacher is taller than the farmer. The doctor is taller than the teacher. The farmer is taller than the soldier. Recall." The rate of presentation was one sentence every 5 sec. A correct response would be to list doctor, teacher, farmer, soldier (in that order) on four lines arranged vertically on a page of a response booklet. Twenty-four randomly selected linear orderings were presented. Four were presented in each input order. Adjectives remained the same within each trial and throughout blocks of 12 sentences. Half the 28 Ss began with a block of sentences using "taller," while the remaining half began with a block of 12 sentences using "shorter."

The principal measure of performance was the proportion of correct linear orderings produced. The results are shown in Table 1.

Insert Table 1 about here

The Ss were twice as likely to get the correct linear orders with Input Order 1 as with Order 6. The overall differences among input orders are highly significant, $F(5,130)=7.83$, $p<.01$. There was a significant overall difference between the two adjectives, $F(1,26)=13.92$, $p<.01$, but the difference is difficult to interpret. On blocks of trials using "shorter," the Ss were requested to write the shortest person at the top of the response sheet, and many Ss explicitly complained that this was harder. It is worth noting that

the interaction of input orders and adjectives was not significant, $F(5,130)=1.38$, so the differences among input orders can be interpreted in a straightforward way.

Before attempting to interpret the differences among input orders, we would like to describe a technique for investigating constructive processes that simplifies the S's task and speeds up the data collection process. The S's task remains the same as does the measure of his performance. The input, however, consists of pairs of digits, each of which the S is to interpret as meaning that those two digits occur in that order in the string he is to construct at output. For instance, the digit pair "84" means that in the output digit string (DS), "8" is followed by "4." Thus, the S might hear the sequence, "eight, four; three, eight; four, one, recall." The correct response would be to write down the DS, 3841, on one line of the response sheet.

In Experiment II, all Ss were given three trials on the six different orders for four-term DSs and also one trial each on the 24 different input orders for five-term DSs. Half the 60 Ss received a block of 24 trials with five-term DSs first; the other half began with 18 trials consisting of three sub-blocks each containing all six input orders of four-term DSs. All four- and five-term DSs were constructed by selecting digits from a random number table with the restriction that no digit could occur more than once in any DS.

The results for four-digit strings are given in Table 2.

Insert Table 2 about here

The order numbers in the left-hand column are arbitrary and reflect the empirical ordering obtained in the first experiment, in order to facilitate comparison with the first experiment. It is apparent that the ordering of the conditions was not quite the same. Order 4, in particular, was relatively much easier in Experiment II than it was in Experiment I. However, Order 1 was again the easiest and performance on it was nearly twice that on Order 6, again the most difficult order. Overall, the differences among input orders was again highly significant, $F(5,580)=21.58$, $p<.001$.

These results suggested a number of hypotheses about the nature of the S's constructive processes. First, we assume that the Ss do not store or retain any information about input sentences or digit pairs. We have not tested this notion ourselves, but Barclay and Potts have. In discussing the remaining assumptions, I will use digit pairs rather than sentences, but the same assumptions apply to sentence input with the necessary changes in wording being made. Second, we assume that, when one or both of the digits in the input matches a digit in a previous input pair, the S integrates the pairs into a single string. For example, in Order 4 given 23 followed by 12, the S constructs the string 123 and retains that. The reader can consult Foos, Sabol and Smith (1974) for detailed discussion of the evidence supporting the second assumption.

The third assumption is the principal concern of the present paper. We assume that, when the digits in the second pair do not match either of those in the first, the S treats the order of input as the best hypothesis about what the order of output will be.

Thus, in Order 5 he will retain the string 1234 after the second pair, and then the string will be confirmed after the third pair, 23. But notice what happens on Order 6. Here, the S should construct the temporary string, 3412, and the presentation of the third pair, 23, should be very disruptive. The S must reorganize the string, inverting 34 and 12. We refer to such orders as inversion orders to characterize the reorganization the S must perform.

There is only one inversion order for four-term series, whereas there are 8 such inversion orders in the 24 possible input orders for five-term series. Table 3 presents the results of Experiment II

Insert Table 3 abc here

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for five-term DSs. The orders are arranged in the table from easiest to most difficult, and it is apparent that 8 out of the 9 hardest orders involve an inversion. The overall effect of input order in these data is again highly significant, $F(23,1334)=10.94$, $p<.001$. A planned comparison of the 8 inversion orders against the remaining 16 noninversion orders was highly significant, $F(1,1334)=185$, $p<.001$, and accounted for 74% of the variance due to orders.

Experiment III was a replication of the input order effect. Eight five-digit input orders were selected, and six observations from each of 15 Ss were collected on each order. The results are presented in Table 4. The numbers for each order given at the left in Table 4 are from Table 3 and represent the ranking of S's

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Insert Table 4 about here

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performance in Experiment II the input order. Again, there are some minor discrepancies between the two experiments, but the overall effect of inversion orders is quite clear. In Experiment III the Ss were on the average more than twice as likely to construct an order that did not require an inversion, and the difference was highly significant, $F(1,658)=203$, $p<.0001$, accounting for 83% of the variance due to orders.

We have also analyzed the errors Ss make in constructing five-term DSs, and while there isn't enough time to describe these analyses in detail, we will present some generalizations. Contrary to what might be expected, serial position of input and serial position of output are not good predictors of where in the DS an error will occur. In inversion orders, the commonest mistake involves a failure to correctly invert the temporarily-held string. For example, look at Order 21 in Table 4. Our theory predicts that the S will form the temporary strings 4512 after the second pair and 45123 after the third. A typical error would be for the S to produce something like 34512. Such error patterns support the assumption that Ss treat input order as output order until one of the pairs disconfirms the expectation. Hence, much of the data from the three experiments can be summarized in a slight rewording of an old proverb, "Just as the pairs incline, so the constructed string is distorted."

References

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Table 1.

Results for Four-Term Series Problems (Experiment I)

		Mean Proportion Correct		
Order No.	Example[a]	Taller	Shorter	Overall
1	A>B, B>C, C>D	.77	.57	.67
2	C>D, B>C, A>B	.73	.45	.59
3	B>C, C>D, A>B	.63	.52	.57
4	B>C, A>B, C>D	.57	.52	.54
5	A>B, C>D, B>C	.46	.41	.44
6	C>D, A>B, B>C	.36	.32	.34

[a] For purposes of illustration, the S's task in each case is to produce the series, ABCD.

Table 2.

Four-Term Digit-String Production

Order No.	Description	Example[a]	Mean Proportion Correct
1	Forward	12, 23, 34	.91
2	Reverse	34, 23, 12	.73
3		23, 34, 12	.73
4		23, 12, 34	.81
5		12, 34, 23	.68
6	Inversion	34, 12, 23	.46

[a] For purposes of illustration, the S's task in each case is to produce the series 1234.

Table 3.

All Input Orders for Five-Digit String Production

	Order	Example[a]	Mean Proportion Correct
1.	Forward	12, 23, 34, 45	.73
2.		23, 12, 34, 45	.72
3.		23, 34, 45, 12	.70
4.		12, 34, 23, 45	.65
5.		23, 34, 12, 45	.65
6.		34, 23, 12, 45	.62
7.		34, 45, 23, 12	.60
8.		23, 45, 34, 12	.58
9.		12, 23, 45, 34	.57
10.		12, 34, 45, 23	.57
11.		34, 23, 45, 12	.57
12.		12, 45, 23, 34	.53
13.	Reverse	45, 34, 23, 12	.53
14.		23, 45, 12, 34	.52
15.		12, 45, 34, 23	.48
16.	Inversion	34, 45, 12, 23	.48
17.		23, 12, 45, 34	.43
18.	Inversion	45, 34, 12, 23	.37
19.	Inversion	34, 12, 45, 23	.30
20.	Inversion	34, 12, 23, 45	.28
21.	Inversion	45, 12, 23, 34	.25
22.	Inversion	45, 12, 34, 23	.18
23.	Inversion	45, 23, 12, 34	.18
24.	Inversion	45, 23, 34, 12	.17

[a] For illustrative purposes, the S's task in each case is to produce the series, 12345.

Table 4.

Effect of an Inversion on Five-Digit String Production (Experiment III)

Order[a]		Example[b]	Mean Proportion Correct
1.	Forward	12, 23, 34, 45	.86
3.	Non-Inversion	23, 34, 45, 12	.76
13.	Reverse	45, 34, 23, 12	.63
14.	Non-Inversion	23, 45, 12, 34	.57
20.	Inversion	34, 12, 23, 45	.40
19.	Inversion	34, 12, 45, 23	.30
21.	Inversion	45, 12, 23, 34	.28
24.	Inversion	45, 23, 34, 12	.24

a Order numbers refer to those used in Table 3.

b For purposes of illustration, the S's task in each case is to produce the series, 12345.